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ABSTRACT

The concept of visual literacy as a performance criterion is briefly considered and difficulties inherent in such a concept are discussed. Previous work in the area of visual literacy is selectively and critically reviewed, noting recurrent problems in research methodology. A rationale is then presented for conducting research which would be relevant to a field investigating the role of visual strategies in problem solving tasks. A 49-item bibliography is appended. (Author/LLS)

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VISUAL STRATEGIES IN PROBLEM SOLVING:
AN ASPECT OF VISUAL LITERACY

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Visual Strategies in Problem Solving: An Aspect of Visual Literacy

The concept of "visual literacy" as a performance criterion is briefly considered and difficulties inherent in such a concept are discussed. Previous work in the area of visual literacy is selectively and critically reviewed noting recurrent problems in research methodology. A rationale is then presented for conducting research which would be relevant to a field investigating the role of visual strategies in problem solving tasks.

Conceptions of Visual Literacy

The term "visual literacy" was introduced over 20 years ago by White (1957) and later popularized by Debes (1969). Although much interest and educational activity has followed, a clear definition of visual literacy has not been established. The most widely held view of visual literacy is that it refers to a set of skills or abilities related to pictorial thinking, learning, and communication skills (Armstrong, 1978; Debes, 1969; Jonassen & Fork, 1975; Pett, 1976). Defining visual literacy as a set of skills has been popular, perhaps because educational practitioners would like to identify and teach visual literacy skills as they now teach verbal literacy. Their notion is that by defining visual literacy as a set of skills, learners' competencies can be assessed and standards of performance established.

There are several problems inherent in a skill-based definition of visual literacy. The first is basic to any concept of literacy: that is, how are criterial levels of performance

established and who establishes them? Verbal literacy is a goal which has widespread support, but there are a myriad of possible definitions of verbal literacy. There is even debate about the nature of skills which signify verbal literacy; a group of British educators wish to expand the requirements of verbal literacy by specifying criterial performance in writing, speaking, and listening skills, as well as reading skills (Southgate, 1971).

The second problem in defining visual literacy in terms of criterial performance is that the skills which underly such a new concept may not be identified or familiar, and instruments may not have been developed to measure them. An individual's visual literacy can only be assessed if that concept has a clear-cut operational definition and if methods are available to characterize the person's performance. It is not clear that such tests exist to assess performance of the visual skills that are implied by the popular conception of visual literacy. The difficulty in setting standards and criteria is discussed by Glass (1978) who suggests that all such attempts either use arbitrary techniques or sophisticated methods which are based upon questionable assumptions. It is especially difficult to create standards of performance for visual skills because there is no widespread agreement on the social value of these skills, and there may be no normative data about performance upon which to compare individuals.

The current concept of visual literacy has not inspired successful research and scholarly inquiry in the area. Past efforts have focussed on social norms and have asked broad questions aimed at improving educational practice. Theory building and empirical hypothesis testing, when conducted correctly, should result in

some findings of great interest and significance to those seeking to improve educational practice. Perhaps the lack of research and scientific theory building have been the main reasons for slow progress in the area of visual literacy. Progress may be facilitated by developing an operational definition of visual literacy, forming hypotheses which will guide research, and evaluating those hypotheses in an attempt to build theory. There are a number of reasons why progress has been slow, and the next section identifies some of the obstacles which have hampered progress in the area.

Past Obstacles to Research in Visual Literacy

The main obstacle to research on visual literacy is that the field has grown up with a rather applied orientation rather than an interest in basic research. Many people who work in this field such as those who are members of the International Visual Literacy Association appear to be practitioners concerned more with applications than basic research. Consequently, more effort seems to go to developing and sometimes evaluating educational programs rather than to conducting empirical research studies.

Most of the literature in visual literacy does not meet the criteria required for scientific theory-building or testing. A requirement of a scientific theory is that it must be testable and can be falsified by empirical evidence (Popper, 1965). Literature in this area often poses untestable questions that are too broadly and imprecisely specified. If a theory cannot be rejected through experience and has an unlimited domain, it is useless for research. Such a theory is a polemic which reinforces old prejudices and does

not yield any new information.

In a number of more advanced fields such as areas in the physical sciences, the criteria necessary for scientific theories have been assured through the use of the hypothetico-deductive method. Using this method, definitions and assumptions are stated clearly enough so that they may generate logical predictions which are deduced from the theory. These predictions may then be tested empirically. If a prediction is not verified by observation, the theory is revised to account for the negative outcome. For a brief introduction to this strategy of theory-building, see Turner (1968, pp. 59-63). Requirements for creating a useful theory of visual literacy using this approach have been described in greater detail previously (Herring, 1979).

Current efforts in the field of visual literacy have shortcomings in the definition, hypothesis generation, and hypothesis testing phases of the hypothetico-deductive method. Previous authors have recognized some of the problems in defining visual literacy (Debes, 1969; Pett, 1976; Spitzer & McNerney, 1975). Current definitions are too vague or expansive to generate clear, testable hypotheses. Three typical definitions of visual literacy illustrate this indeterminacy. Visual literacy has been defined as a "group of vision competencies a human being can develop by seeing and at the same time having and integrating other sensory experiences" (Debes, 1967, 1969). Visual literacy has also been defined as "a person's ability to understand and evaluate.... (visual languaging) as well as his or her ability to use visual languaging to communicate" (Pett, 1979). Finally, visual literacy is conceived as "a concept which emphasizes the use of

non-verbal means...to facilitate and deepen conceptual learning" (Schiller, 1979). It is not readily apparent how these three definitions differ from one another, and their imprecision may be a reason that they have not produced more fruitful research.

Lack of clear definitions hampers hypothesis generation because it is not possible to derive predictions from poorly defined concepts. Other definitions are also poorly articulated or unclearly stated. For instance, an article by Schiller (1979) discussed visual literacy using uncommon, unfamiliar terms such as *resonation*, *cognetting*, *relatable*, etc. Concepts need to be carefully and simply defined for researchers to make testable predictions. In order to make valid experimental inferences, one must begin by defining a concept clearly, specifying instances of the concept, and hypothesizing some relations between elements of the theory. After these steps are taken, a researcher can then use the theoretical framework to predict the effect that an operation has on some outcome, conduct an experiment, and compare the observed outcome with the predicted outcome.

Unfortunately, much of the literature concerning visual literacy is not oriented to hypothesis testing. Ironically, an early article by Williams (1970) is one of the few which deals explicitly with hypotheses, (see also Debes & Williams, 1978). The literature is often atheoretical, dealing only with educational programs and practices (Fransecky & Debes, 1967; Fransecky & Ferguson, 1973; McKim, 1977; Ross, 1972; Visual, 1976). These descriptions of educational practices do not constitute tests of theory, though they may provide useful evaluations of educational programs. Evaluative research assesses whether a program is

successful in achieving specified goals in a particular context and no causal attributions can be made as to why the program is observed to be successful or not. Properly controlled investigations, on the other hand, seek to make causal inferences about what is occurring and why it occurred--in other words, what is causing the success or failure. Empirical research tests the probable truth of hypotheses. This latter type of investigation demands that there be internal validity or control so that comparisons can be made.

Carefully controlled research designs are especially important in instructional situations because these settings are especially susceptible to the "Hawthorn Effect", which is an increase in learner performance due solely to an innovation (Blatt & Garfunkel, 1973). In other words, an evaluation of a new visual literacy program will probably indicate some positive result but the same positive effect could probably be obtained by starting a verbal literacy program, a physical change in the classroom, or any number of other changes which signal to the learner that something special is being done to help them. This effect hampers scientific research in the attempt to discover the real causes of observed effects. Innovation may be valuable for its own sake to the practitioner, however. Southgate (1971) recognizes the potency of innovation in literacy.

I think it advantageous that schools are free to choose any medium, method, or reading materials they prefer, as experimenting with new techniques or equipment rarely fails to inspire the teacher and so benefit the children almost regardless of the nature of the innovation. Although I have seen classes dampened by the lack of sparkle in teachers who were themselves dulled by the dreariness of routines and familiar reading schemes, I have not come across children whose reading has suffered when their teacher was filled with enthusiasm by the stimulus of experimenting. (p.13)

If a general performance increment is produced by any change in educational practices, it is impossible without adequate controls to determine whether the improvement is due to the nature of the innovation or simply to its novelty.

The contrast between scientific and evaluative research is discussed by Glass (1972) who distinguishes between "elucidatory" and "evaluative" inquiry. Elucidatory inquiry is concerned with constructing models and theories for the goal of explanation and understanding. This type of inquiry seeks to determine cause-and-effect relationships. Evaluative inquiry, on the other hand, is concerned with assessing the effects of a particular program but cannot validly discover the underlying causes of those effects. Based on the lack of compelling empirical evidence in the early 1970's, Glass concluded that only evaluative inquiry can be justified with the limited resources available to education. In light of new research and improved methodological practice in educational research (Wittrock & Lumsdaine, 1977), visual literacy can surely profit from empirical research, using educational settings as field tests for hypotheses about visual literacy.

Finally, a major question is whether there are significant skills which require vision in educational situations but which are not teachable skills. If some skills are not readily taught because they are innate or learned prior to formal schooling, there is no justification for teaching them in a formal educational program. Another relevant question is whether there is justifica-

tion for teaching visual skills in a curriculum rather than providing other types of innovative programs in the schools. There is yet no evidence that visual instruction is more effective in reaching certain goals than other programs which devote a similar amount of attention to the learners and present them with novel experiences. Visual literacy programs could be successful in reaching their goals due to the Hawthorn Effect, and could be no more effective than other novel programs in, for example, music, meditation, volleyball, etc.

Research on Visual Literature Strategies in Memory and Problem Solving

One of the problems related to visual literacy is that it has been broadly defined, when defined at all. From its inception, a number of disciplines have been considered relevant such as philosophy, psychology, etc. (Debes, 1969). This breadth of interests was recently shown by one author who contends that visual literacy should deal with the means of interpreting all visual artifacts (Levison, 1979). In the interest of progress in visual literacy, it may be wise to first limit its domain of topics and to define a field of research which is "possible small" rather than "impossibly large." One manageable possibility is that research on visual literacy concerns the study of educational or classroom skills which a) require or profit from vision, and b) demonstrate an effect on instructional performance. This definition shifts the focus to operationally defined visual strategies that can be shown to facilitate

learning. There is already a body of literature which deals with visual learning strategies and some of those strategies will now be discussed.

Visual strategies may aid rote memorization and learning a second language. Visual imagery techniques have been suggested as aids to memory in popular and professional literature (Bower, 1970; Lorayne & Lucas, 1974; Luria, 1968; Paivio, 1971). Studies conducted by Atkinson and his colleagues (Atkinson & Raugh, 1975; Raugh & Atkinson, 1975) have also demonstrated that a mnemonic "keyword" system is a highly effective technique for learning vocabulary in a second language, and it is at least as effective as any other strategy people would choose to use. In the keyword system, an individual is first instructed to form a phonetic association between the foreign word and a "keyword", which is a word in English which is phonetically similar to the foreign word. The learner then is instructed to use the keyword in constructing a mental image which represents the meaning of the foreign word. For example, to remember the Spanish word "caballo" meaning "horse", the learner would mentally imagine a horse biting or interacting in some other way with a cob (because "cob" is the keyword). This example involves rote memory, but a recent review article cites evidence that imagery techniques also facilitate memory for more meaningful learning (Lutz, 1980).

Another stream of evidence suggests that skilled viewers store meaningful visual information in "perceptual chunks" of items that are functionally related. This line of research began with studies on memory for chess pieces (de Groot, 1966).

Researchers found that sophisticated players could remember the locations of more chess pieces than novices when those pieces were arranged as if an actual game were in progress, but experts remembered no more than novices when the pieces were arranged at random. More recent research found similar results on memory for schematic diagrams. When a schematic diagram was shown to both naive and experienced electronic technicians, the technicians recalled more of the components in functional groups or "chunks" than did novices (Egan & Schwartz, 1979). These results suggest that "perceptual chunking" occurs during initial perception. The concept of perceptual **CHUNKING** may have instructional implications by suggesting that informative displays would be better recalled if they were constructed with related items in close proximity to one another. Another suggestion is that naive learners would profit from repeated exposure to representations of functional units or components, so they may more readily form visual chunks of these meaningful units when presented with additional diagrams.

Another area of research on visuals has investigated whether learner-generated diagrams facilitate technical problem solving. Some of the classic literature in human problem-solving research suggests that the initial perception and representation of a problem situation is an important factor affecting its' solution (Posner, 1973). Many of these researchs demonstrated that an initial representation could have inhibitory effects on solving a problem. This inhibition may occur if the problem's solution requires a strategy different from those used in previous problems ("Einstellung"), or if the materials available for use in the

problem situation need to be used in a novel way in order to solve the problem (functional fixedness).

It is possible that the initial representation of a problem as a diagram may have effects which facilitate problem solution. The procedure of creating sketches during problem solving has always been part of training in the physical sciences and engineering (see also Jorgensen, 1978), and may aid problem solving by eliminating distracting detail. Making diagrams may also force a learner to clarify his thoughts to identify the relevant attributes and the relations between them in the problem situation. However, if the problem requires a novel approach for solution, a visual strategy may actually inhibit performance (Wicker, Weinstein, Yelich, & Brooks, 1978).

Recently, a paper by Larkin (1979) suggests that a detailed physical representation of a technical problem is a powerful aid to experts in solving elementary mechanics problems. Protocols from her subjects showed that experienced problem solvers usually first develop a qualitative sketch of a problem situation before attempting an algebraic solution and they usually identify all the relevant forces during their initial qualitative sketch. Naive problem solvers more often first attempt an algebraic solution and represent the physical forces in a detailed representation only when the current information is not sufficient for algebraic solution. She suggests that errors made by inexperienced subjects develop in part because the algebraic goal often can be satisfied with an equation based upon an incomplete analysis of the physical forces in the problem.

Finally, does the ability to "visualize" contribute to or is correlated with the ability to perform other tasks? Many biographies of scientists and mathematicians suggest that some form of vivid visual experience was intimately involved in making their greatest discoveries or inventions (see Hadamard, 1945 and Shepard, 1978 for fascinating reviews), (Footnote 1). A number of books have been produced which discuss visual imagery as a technique in problem-solving, and contain exercises in such techniques (Gordon, 1965; McKim, 1972, 1977; Samples, 1976; Samples & Wohlford, 1973). Recently research in experimental psychology has been investigating questions regarding visual processes and complex tasks (see Just & Carpenter, 1976; Shepard & Metzler, 1971), and it may now be possible to investigate the role of imagery instructions on tasks of instructional importance.

An educationally relevant question asks the relation of imagery instructions to solving tasks required by standard curricula, such as geometry tasks. Some of these problems require both information about the physical representation of the elements in the diagram, and knowledge of geometrical axioms, and it may be possible to facilitate solutions of these problems through explicit imagery instructions. Landa (1976) presents a set of instructions designed to aid this type of problem-solving, and they include heuristics which involve physical manipulation of the given geometrical image (constructing additional diagonals, tangents, studying the relations between the component parts...). Greeno (1976) analyzes the information and steps required to provide a proof of triangle congruence, and constructs a computer

simulation capable of such a proof. Greeno and Landa both present analyses of subject protocols which may help develop a method to classify subjects' strategies in completing these tasks.

Visual imagery, or manipulation of given ^{Visual} information may be neither necessary nor sufficient for solving some geometrical problems, so instruction in geometrical axioms should not be slighted in favor of imagery instructions. I fear that many people interested in visual literacy are "visual enthusiasts" who may overemphasize visual aspects to these types of problems. There may be some problems for which manipulation of visual information (such as auxiliary construction, or rearrangement of inscribed figures) is necessary and sufficient for a solution, and other problems in which axiomatic information is sufficient and visual information is not required.

Summary

In this paper, I have attempted to show that visual literacy is now an ill-defined concept, and the concept of literacy is itself uninteresting as a basis of research. Typically, literacy is defined as a criterion level of performance of some communicative skill that is desired for the individuals in a given culture. By this interpretation, visual literacy is a criterion level that is decided by the arbiters of culture and education. Though this concept of visual literacy may be unimportant, an alternative concept is suggested which defines visual literacy as an experimental study of the relation of visual skills to instructional tasks.

Visual literacy would surely progress as a field of inquiry if more experimental studies were conducted investigating relevant issues. At present, research is hampered by vague definitions, and the inability to generate precise or testable hypotheses. Another reason for slow progress is that much concern in visual literacy represents vested professional interests, and in general these interests inhibit some research questions from being asked.

I believe that an interest in visual literacy may yield new knowledge if it is restricted to a narrower domain of interests. Some relevant research areas are the use of visual images as mnemonic devices in second-language learning, the role of making diagrams as an aid to technical problem solving, memory organization of diagram elements into "chunks" of functional units when the diagrams are presented to skilled observers, and the role of visual imagery in solving geometrical problems.

Footnotes

1. Many who cite this literature, such as Gordon, McKim or Samples fail to note that these scientists and mathematicians are often outstanding in a number of attributes, and that a visualization ability may not be responsible for the unique solution, or may be merely an epiphenomenon of the factors which lead to a solution. I believe that this literature can be misleading because of its stress on the nonverbal and non-notational aspects of these solutions; many of these innovators had mastered formal notational systems with which they later characterized their discoveries (Hadamard, 1945; Randhawa, 1978, pp. 205-206).

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